

Banded Iron Formation Discovery at Arkenu and Al Uwaynat Regions and its iron and gold potential, southeast Libya.

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ABSTRACT

The country rocks are Archean , proterozoic and orthogneisses with subordinate ultramafic .

Pan African granitoids are intruded into order of undifferentiated Precambrian metamorphic rocks. Paleozoic and Mesozoic sediments, unconformable over the Precambrian rocks. Precambrian and younger crystalline rocks occurs in southeast Libya, where covered an area about 10,000 km².

The geological mapping of the east Al Uwaynat region in the last years ,led to discovery of big occurrence of Banded Iron Formation (BIF), to west and south Jabal Al Uwaynat ring complex and around Jabal Arkenu , Jabal bahri , ring complexes , bounded by lat 21⁰ 10` 00`` - 22⁰ 40` 00`` N and long. 24⁰ 15` 00`` - 25⁰ 00` 00`` E .

Banded Iron Formation, which could be considered as iron source and oftenly of gold bearing. The investigation comprised field mapping of the region on scale 1:250,000, to verify occurrence of BIF, gold, and iron oxides.

In the studies area basement inliers the predominant - trend of the folds axes in NE-SW but locally this principal trend direction to NNE- SSW or E-W.

The Banded Iron Formation (BIF), crop out as highly folded and faulted beds and extending for several kilometers, some are 11 km long and up to 250 m width.

The geological mapping work revealed the presence of huge deposits or big reserve of BIF, chemical analyses showed that iron oxides (Fe₂O₃) content range of 25% to 65% , from the rock and MnO as well as P₂O₅ were in suitable ration. And mineralogical studies that iron ore minerals are goethite, hematite and magnetite, which alternate with silica (SiO₂), sulphides occur in trace amount. Fire assay and Atomic absorption analyses proved that most of BIF samples are gold bearing and range from 0.3 to 5.7g/ton.

Based on the geological mapping and geochemical exploration work ,the basement rocks of Al Uwaynat region very promising and more extensive and detailed exploration is essential in order to estimate ,the gold and iron content in BIF at outlines the mineralized zones within the ore bodies .

اكتشاف طبقات الحديد الشرائطي في مناطق أركنو والعوينات واحتمالية تواجد الذهب والحديد بهما، جنوب شرق الجماهيرية العظمى

جيولوجي/ سويسى خليفة سويسى
إدارة البحوث الجيولوجية والتعدين
مركز البحوث الصناعية

الملخص

صخور المنطقة عبارة عن صخور حقب الحياة السحيقة (الاركني) وهي صخور البارنايس والارتونايس مع تداخلات من صخور الجرانيت وصخور ما فوق القاعدة والتابعة لعصر ما قبل الكمبري.

وتعلو صخور هذا العصر صخور حقب الحياة القديمة والتي تغطي بسطح عدم توافق (صخور الكونجولوميرات) وتغطي صخور القاعدة حوالي 10 آلاف كيلومتر مربع في هذه المنطقة.

التخريط الجيولوجي في السنوات الأخيرة بمنطقة العوينات الشرقية أكتشف تواجدات كبيرة لطبقات الحديد الشرائطي في غرب وجنوب المعقد الحلقي لجبل العوينات وحول كل من المعقد الحلقي لجبل أركنو وجبل بحري، ويمكن حصر المنطقة التي تتكشف بها هزة الصخور بين خطوط الطول والعرض الآتية.

lat 21° 10` 00`` - 22° 40` 00`` N and long. 24° 15` 00` - 25° 00` 00`` E.

طبقات الحديد الشرائطي تعتبر مصدر رئيس للحديد وفي بعض الأحيان يرتبط تواجد الذهب بها. والتحري والبحث الذي شمله التخريط الجيولوجي للمنطقة بمقياس رسم 1:250 ألف إشارة إلى وجود طبقات الحديد الشرائطي، والذهب والحديد.

وتأخذ صخور القاعدة وخاصة الصخور المتحولة عدة اتجاهات والاتجاه السائد لمحور الطيات هو شمال شرق - جنوب غرب، أما الاتجاه الموضعي أو المحلي شمال شرق - جنوب جنوب غرب، أو شرق - غرب.

تظهر طبقات وعدسات الحديد الشرائطي متأثرة بالعديد من الطيات والصدوع والتي تأثرة بها المنطقة منذ عصر الاركني وحتى الآن.

وبتراوح سمك الطبقات ما بين عشرات الأمتار وحتى مئات الأمتار، بينما امتداداتها من عشرات الأمتار على هيئة عدسات إلى عشرات الكيلومترات على هيئة طبقات تتقطع بالعديد من الصدوع الضاهرة بالمنطقة.

وأشار التخريط الجيولوجي إلى وجود رواسب كبيرة أو احتياطيات كثيرة ومن خلال نتائج التخريط وبعض الدراسات الاستكشافية تشير إلى وجود نسبة أكسيد الحد يديك تتراوح ما بين 25% وحتى 65%، ونسبة أكسيد المنجنيز وخامس أكسيد الفسفور في المستوى الطبيعي لصناعة الحديد.

ومن خلال الدراسات الميكروسكوبية تم معرفة أهم المعادن المكونة لهذه الطبقات، وهي عبارة عن معدن الجيوتايت والهيماتايت والمجناتايت والتي تتعاقب مع ثاني أكسيد السيليكون مكونة طبقات رقيقة على هيئة أشرطة.

وإشارة التحاليل بواسطة التقدير الناري والامتصاص الدري للعديد من العينات بأن نسبة الذهب تتراوح ما بين 0.3 - 5.7 جرام /طن.

Introduction

This paper briefly introduces some of the previous works east Al Uwaynat region and discusses the occurrence of Banded Iron Formation (B.I.F.) and minerals potential of gold and iron in this rocks .The south eastern corner of Libya received little attention from authors and authorities especially from the economic minerals deposits point of view .

The first exploration for mining purposes was that Morholz (1968) due to limited time did not indicate visible occurrence of useful minerals.

Bell and sandford (1971), quoted the finding Mn minerals of mineralogical interest only.

Although many studies are available on the area, no systematic regional geological and geochemical exploration in the area. Hunting Geological and Geophysics Ltd., (1974), conducted a systematic geological and mineral exploration survey of about 28,500 Km² of southeast Libya.

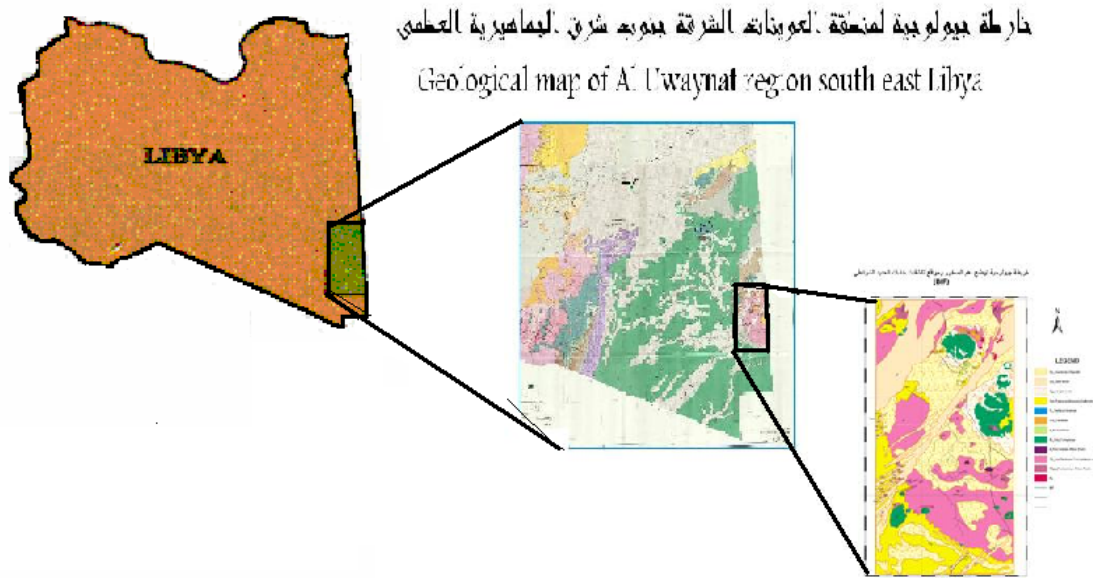
Later survey by C.R.G. (1980), also recommended by detailed exploration in the area. Recently, and through the new policy of the I.R.C. and within the national program of sustainable development of southern Libya, some efforts were devoted to explore this virgin area.

Since (1992) a joint project between industrial Research Center (I.R.C.) of Libya and geological survey of Egypt (E.G.S.M.A), Planned to map explore. The Libyan–Egyptian border sheets (Jabal Arkenu NF,35-5 Jabal Al Uwaynat NF 35-9, and Jabal Asabah NF 35-1). Most of the present authors participated in this mapping works of this sheets on scale 1:250,000.

The main results of this work is recording anomalous gold and Iron contents in association with Banded Iron Formation and was discovery of huge deposits of this rocks ,crops out in the Al Uwaynat region ,especially in the area located between:

lat $21^{\circ} 10' 00''$ - $22^{\circ} 40' 00''$ N and long. $24^{\circ} 15' 00''$ - $25^{\circ} 00' 00''$ E .

Fig (1)



The main route could be reached from Al Kufra Oasis southeast Libya , through desert route directed to the south east 250 Km, and traverses several sand dunes , Sief Esabean , Sief El Matar , Sief Arkenu , Sief Al Uwaynat, and sief Morday to reach Soudan boarder.

The main dominant high features are Jabal Al Uwaynat and Jabal Arkenu rise above sea level 1934 m and 1436m ,Jabal Bahari ,Jabal Babein ,Chazzi hill ring complexes and several plugs of sub circular shape as east Chazzi hill ,Sandra hill and Youragadah hill .

The investigation area is a part of Al Uwaynat region of high ground occurring in SE of Libya ,SW of Egypt and NW of Soudan .

The area is covered mainly by metamorphic rocks of Archean to early proterozoic age (Klerkx 1980 ,sultan et.al.1996),which were intruded by granitic rocks ,series of ring complexes roughly aligned along N-S trend and overlain by Paleozoic and Mesozoic sediments .

Tertiary basalts as plugs and dikes intrude both the basement and sedimentary rocks .

Quaternary deposits covers vast area as sand dunes and sand sheets.

The occurrence of gold within B.I.F. in Precambrian rocks are reported from Al Uwaynat region in Libya part (side), Hunting 1974 ,but maximum assay recorded was 0.15 ppm , Khalid and Diaf 1996, recognized in many places occurrence of gold within B.I.F. contained gold ranging from 0.3 to 5.7 g/ton .

The association of gold within B.I.F. in Precambrian sequences have been recognized in many parts of the world such as Canada, Brazil, South central Africa and Zimbabwe (Fripp 1976). So prospecting for gold in the B.I.F. of Al Uwaynat region was initiated .

The present paper ,present some preliminary results of the exploration works could be considered as iron source and oftenly of gold bearing in some selected areas of B.I.F. outcrops .

Both field and laboratory works revealed that areas promising and detailed exploration suggested .

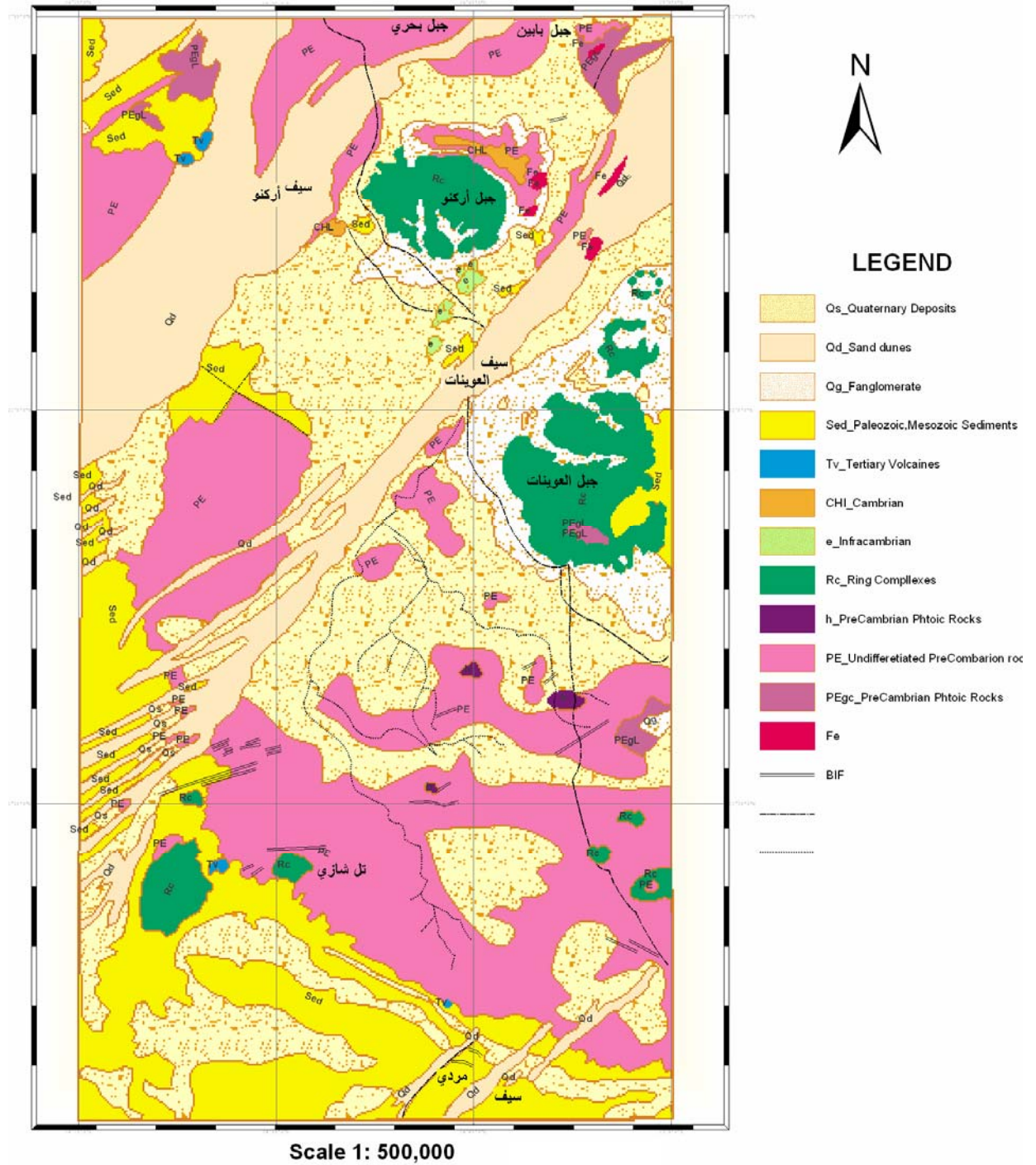
Regional Geological Setting

The general geological of Al Uwaynat region carried out the Joint Project between the IRC .(Tripoli)and EGSMA (Cairo) .team revealed that the area under investigation is covered by the following rock units arranged from the oldest to the youngest :-

- Quaternary deposits cover most of the area .
- Tertiary volcanics
- Paleozoic –Mesozoic sediments .
- Ring complexes .
- Infracambrian sediments .
- Precambrian Plutonic rocks .
- Ultrabasic rocks .
- Undifferentiated Precambrian rocks .

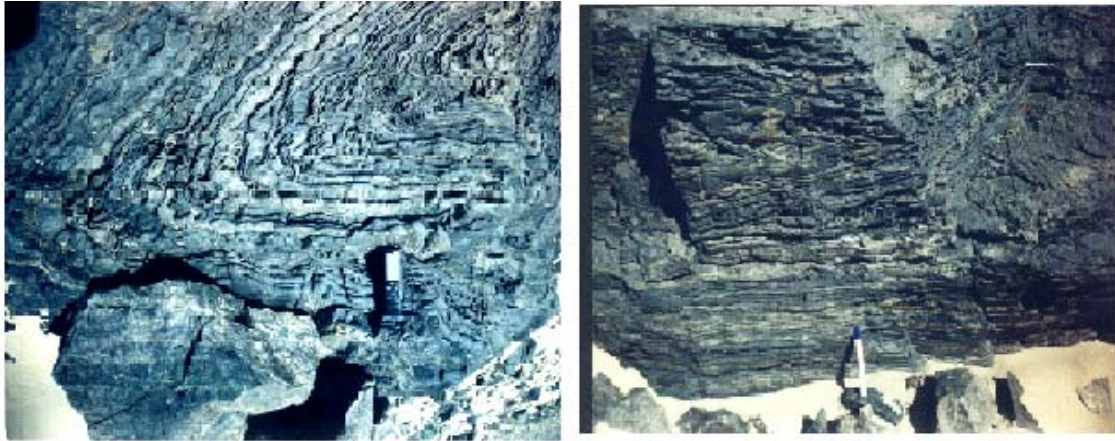
Fig (2)

خريطة جيولوجية توضح أهم الصخور ومواقع تكشفات خامات الحديد الشرائطي (BIF)

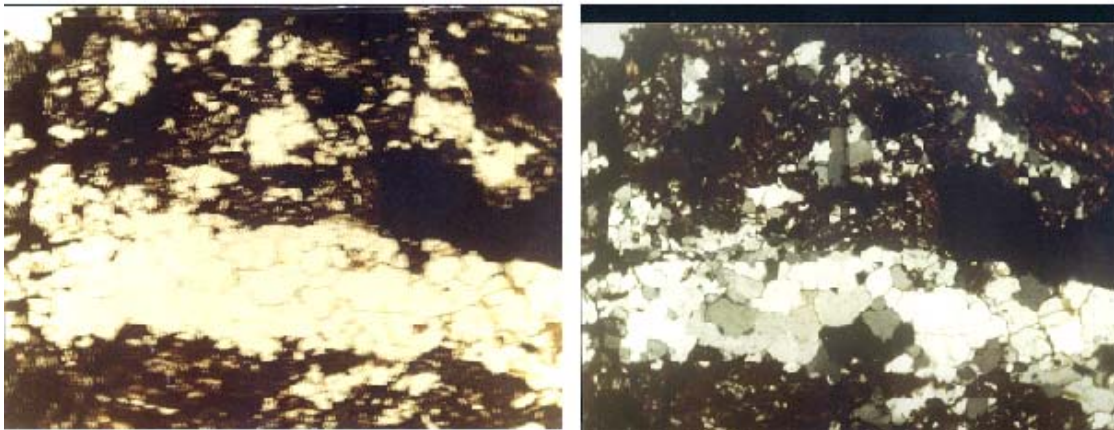


The oldest Precambrian rocks in Al Uwaynat region are composed in the plains surrounding the prominent features of the ring complexes, these rocks consists of para and ortho-gneisses of granulite and amphibolite facies.

The para-gneisses include quartzofeldspathic gneisses, migmatite gneisses ,biotite gneiss, quartzite marble with calc-silicate, as well banded iron formation (BIF) .photo no. 1,2,3,4.



Highly folded Banded Iron Formation or Quartz-magnetite-gneisses covered by Quaternary sand sheet, at the northern part of Chazzi hill.



**Quartz-magnetite-gneisses.
Al Uwaynat area P.L. X 40**

**Quartz-magnetite -gneisses
Al Uwaynat area C.N .X 40..**

The ortho-gneisses consists mainly of diorite gneisses ,granite gneisses and porphyroblastic granitoides .

Ultra basic rocks are intruded with the undifferentiated Precambrian rocks and major exposed 30 km south of jabal AlUwaynat ring complex .

They are mainly built up to serpentinitic rocks and quartz-carbonate rocks (Listaewenite) .

The serpentinite exposure forms a sub rounded mass and exhibit shearing synchronous with the foliation of the gneisses indicating pre to syn-tectonic intrusion of this mass, emplacement with controlled by deep-seated fault taking NE-SW ,structural trends and are in most cases associated with Banded Iron Formation beds (Lagha.s.a.1981).

Precambrian Plutonic rocks , intrusive rocks comprise calc-alkaline porphyritic granite , granodiorite and adamellites as well as alkaline granite ,gabbro and subparallel mafic dykes swarms.

The basement rocks of Al Uwaynat region were subject to uplifting and doming by the end of the Paleozoic .The erosion of the basement rocks in the core of this dome .Later on ,and during Tertiary epoch, the area became unstable and thin led to the extrusion of the volcanic rocks from of plugs and dykes (Naim.G.M.,et al. 1998). Infracambrian sediments crop out in a discontinuous NNE-SSW .Trending , associated with major fault zone ,to the east and north east of jabal Arkenu at several isolated localities ,these sediment overly Precambrian rocks .

Ring complex, occupy the central part of the area and are Paleozoic age .

Paleozoic-Mesozoic sediments, Cambrian, Ordovician are restricted to the flanks of jabal Arkenu and jabal Al Uwaynat, Devonian, Carboniferous and Cretaceous rocks, unconformable with undifferentiated Precambrian rocks.

Tertiary volcanics in the form of basaltic, trachytic and phonolitic plugs, sills, and dikes. Quaternary deposits cover most of the area.

Field studies and sampling

This paper deals with the results of geological mapping an large scale 1:250,000,and some geological and geochemical prospecting and most promising areas for future exploration are delineated during geological mapping promising all mineralized outcrops of the banded iron formations were traced and sampled .

The sampling of the mineralized beds along profiles traversed cutting perpendicular to the strike of the beds of Banded Iron Formation, collecting 95 samples from this beds for gold analyses and complete chemical analyses for some representative samples to indicate complete chemical oxides and iron contents.

Geological and Geochemical exploration during the mapping

I –Geological exploration

On the basis of recorded associate of gold deposits with BIF in undifferentiated Precambrian rocks ,the al Uwaynat region was chosen for study.

The field observation shows quartz magnetite gneisses BIF ,occurs as lenses and beds alternating with amphibolites and Para gneisses (quartzofeldspathic gneisses ,quartzite ,biotite gneisses, marble with cac-silicate)as well as banded iron formation ,in highly folded ,faulted and sheared.

The BIF exposures as lenses at the northern region and thickness ranges from 15 meters to 50 meters ,where their length reaches up to 300 meters .

Further ,the southern region exposures as beds ranging in thickness from a dozen meters to 250 meters and ranging in length from hundreds meters to 11 km ,like outcrops west ultrabasic body.



Banded Iron Formation as lenses in sand dunes in Al Uwaynat and Arkenu areas .

This outcrops as beds or lenses forming relatively high topographic ridges striking NNE-SSW, E-W, and in most cases NE-SW ,dip at angle ranging from 40° to 60° within the main outcrops of Precambrian basement. The deformation as manifested by clear gneissosity and folding is well defined and harmonious with the regional deformation, of the country rocks and evidently the BIF ,ore bodies have the same structural history .

Most of the beds abruptly by faults displacements or by passing under thick sand sheets or sand dunes.



**Banded Iron Formation bed .K6 .
Looking to the east**



**Band Iron Formation at A7
Looking to W**



**B I F bed showing low land . Notice
Trench show weathering of BIF. At U9.
Looking to the NE**



**Banded Iron Formation in contact
With calc-silicate and marble**

The BIF are widely distributed in the al Uwaynat region.

The outcrops exposed east Jabal Arkenu as rounded to sub rounded big hills near Arkenu ring complex and in the sand dunes siaf Al Uwaynat and as elongated peaks taking NE-SW trend ,outcrops represented thick beds covered by sand dunes .the southern Al Uwaynat region ,outcrops occurs as beds, however, west Ultrabasic body, south Jabal Al Uwaynat ring complex, as elongated ridges striking NE-SW and dipping NW by angle 60° and extended along strike about 11 km long and thickness varies from 50m at east and 250 m at the west of the outcrops or beds .

An other beds occur north Chazzi hill and north saif Mordy.

The Banded Iron Formation is composed of alternating bands of iron-rich and microcrystalline silica bands ,the iron-rich bands consists of goethite, hematite and magnetite with some specularite, while the microcrystalline silica bands are mainly quartz, chert and jasper .

These outcrops shows that BIF is of the oxide faces while detailed mineralogical studies showed that other faces .the most exposed of Banded Iron Formation beds are intersected or intruded by different types of quartz veins and listwaenites (silica –carbonate) are associated with BIF, and serpentinites which are reddish brown ,hard some Centimeter thick while may reach up to 10m .

II-Geochemical exploration

A Geochemical exploration programs were carried out using bed rock geochemistry as a tool for gold and iron exploration .

This work was conducted to throw some light of the economic potentiality of these remote region, during the geological mapping programs revealed that mineralization at these areas confined to banded iron formation ,(Au ,Ag and Fe).

The field observations and analyses showed that BIF outcrops at east Jabal Arkenu are more rich in iron content in comparison with that beds which occur south Jabal Al Uwaynat ring complex.

Field checking shows strong magnetic anomalies in the basement zone are associated with lenses and beds of banded iron formation . the possible value of the iron bearing Precambrian quartzite ,depends on proving larger quantities of ore .

Airborne magnetic data suggests that the banded iron formation has subsurface extent.

The microscopic investigation study shows the rock is composed of quartz and iron oxides ,arranged in gneissic texture ,quartz crystals shows light bands are highly sheared ,fractured and shows wavy extinction .

The opaque minerals shows black bands and form ore more than 50% from the rock and represented by hematite, magnetite and goethite. Magnetite minerals occurs as fine to medium grained irregular grains, commonly of inter located boundaries. Hematite occurs as coarse to fine, tubular subhedral to anhedral crystals, the accessories are feldspar ,apatite, chlorite and muscovite .

The quartz magnetite gneisses were chemically analyzed for major oxides

It show that Fe_2O_3 % ranges from 25 % to 65%from the rock ,the representative analyzed (32) samples of bed rocks ,where collected from Arkenu and Al Uwaynat Regions during the geological mapping program .The complete chemical analyzes to determine the oxides and content of iron and determined gold mineralization in the bed rocks of banded iron formation by Atomic absorption and Fire assay.

It shows in this tables

| sample no. | 556 | 570 | 634 | 636 | 640 | 641 | 650 | 652 | 671 | 672 | 2220 |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Oxides | | | | | | | | | | | |
| Sio2 | 44.77 | 45.72 | 44.55 | 39.22 | 37.67 | 42.19 | 31.41 | 38.79 | 41.25 | 46.43 | 37.09 |
| Tio2 | 0.52 | 0.42 | 0.35 | 0.36 | 0.28 | 0.08 | 0.08 | 0.09 | 0.16 | 0.29 | 0.13 |
| Al2o3 | 7.55 | 0.42 | 0.43 | 0.42 | 0.28 | 0.55 | 0.27 | 0.41 | 0.47 | 0.36 | 0.41 |
| Fe2o3 | 41.04 | 50.28 | 52.56 | 56.66 | 58.38 | 54.43 | 65.11 | 56.91 | 55.59 | 49.63 | 58.43 |
| Ngo | 0.43 | 0.09 | 0.12 | 1.5 | 0.36 | 0.29 | 0.58 | 0.39 | 0.29 | 0.43 | 0.48 |
| Cao | 2.42 | 2.35 | 0.94 | 1.41 | 1.27 | 1.14 | 1.48 | 0.87 | 1.01 | 1.27 | 1.34 |
| Mno | 0.04 | 0.03 | 0.03 | 0.05 | 0.07 | 0.04 | 0.06 | 0.05 | 0.07 | 0.06 | 0.07 |
| P2O5 | 0.25 | 0.16 | 0.13 | 0.22 | 0.43 | 0.43 | 0.21 | 0.28 | 0.18 | 0.28 | 0.5 |
| S | 0.37 | 0.31 | 0.46 | 0.53 | 0.64 | 0.73 | 0.23 | 0.48 | 0.52 | 0.48 | 0.31 |
| L.O.I. | 3.61 | 0.52 | 0.36 | 0.31 | 0.46 | 0.17 | 0.1 | 0.27 | 0.42 | 0.61 | 0.1 |
| Au | 0.9 | 1.5 | 0.52 | 1.08 | 1.8 | 5.7 | 1.05 | 2.1 | 0.69 | 2.04 | 1.2 |

| sample no. | 1697 | 1726 | 916 | 938 | 2072 | 2146 | 2205 | 2097 | 2109 | 2207 | 333 |
|------------|-------|-------|-------|-------|------|-------|------|-------|-------|-------|-------|
| Oxides | | | | | | | | | | | |
| Sio2 | 35.53 | 47.91 | 58.6 | 28.65 | 56.9 | 55.02 | 52.6 | 53.73 | 51.8 | 53.79 | 43 |
| Tio2 | 0.06 | 0.25 | 0.03 | 0.05 | 0.01 | 0.24 | 0.01 | 0.07 | 0.05 | 0.04 | 0.05 |
| Al2o3 | 0.95 | 0.55 | 0.11 | 0.11 | 0.21 | 1.94 | 0.21 | 0.19 | 0.33 | 0.22 | 1.03 |
| Fe2o3 | 61.02 | 49.63 | 39.32 | 65.5 | 37.9 | 34.93 | 43.1 | 41.86 | 54.17 | 43.27 | 47.19 |
| Mgo | 0.39 | 0.34 | 0.02 | 0.02 | 0.16 | 0.16 | 0.02 | 0.11 | 0.05 | 0.06 | 1.26 |
| Cao | 1.14 | 1.31 | 0.36 | 0.38 | 1.58 | 1.33 | 1.2 | 1.12 | 0.35 | 0.22 | 1.02 |
| Mno | 0.08 | 0.05 | 0.01 | 0.95 | 0.12 | 0.1 | 0.75 | 0.11 | 0.13 | 0.15 | 0.11 |
| P2O5 | 0.12 | 0.09 | 0.18 | 0.87 | 0.13 | 0.11 | 0.03 | 0.08 | 0.09 | 0.02 | 0.22 |
| S | 0.34 | 0.33 | 0.42 | 0.37 | 0.39 | 0.42 | 0.32 | 0.45 | 0.53 | 0.41 | 23 |
| L.O.I. | | 0.85 | 0.14 | 1.39 | 5.15 | 1.4 | 0.95 | 0.84 | 1.4 | 0.1 | |
| Au | 1.5 | 1.35 | 3 | 2.1 | 1.3 | 1.5 | 5.5 | 1.2 | 1.2 | 1.5 | |

| sample no. | 710 | 9 | 2108 | 2154 | 2173 | 915 | 935 | 12184 | 1015 | 1075 |
|------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Oxides | | | | | | | | | | |
| Sio2 | 51 | 39.21 | 38.1 | 47.1 | 35.5 | 44.85 | 56.05 | 54.6 | 46.39 | 36.14 |
| Tio2 | 0.24 | 0.06 | 0.22 | 0.93 | 0.23 | 1.1 | 0.38 | 0.05 | | |
| Al2o3 | 3.03 | 0.38 | 1.02 | 5.09 | | | | 0.6 | | |
| Fe2o3 | 42 | 56.74 | 54.99 | 43.99 | 65.19 | 51.3 | 37.5 | 41.3 | 52.23 | 59.42 |
| Mgo | 0.29 | | | | | | | 0.3 | | |
| Cao | 0.23 | 0.37 | 1.68 | 1.68 | | 1.12 | 8.45 | 0.45 | | |
| Mno | 0.06 | 0.04 | | | | 0.08 | 0.15 | 0.12 | 0.01 | 0.01 |
| P2O5 | 0.12 | | | | | | | 0.13 | 0.33 | 0.23 |
| L.O.I. | | | 1.21 | 0.14 | 1.46 | 1.08 | 1.23 | | | |
| Au | | | 1.5 | | 0.6 | 2 | | | | |

Conclusion and recommendation

Through the scientific co-operation between I.R.C. and E.G.S.M.A. ,the field of regional mapping of Arkenu and AL uwaynat region , a regional geological and geochemical prospecting work ,was concluded that ,throw some light on the economic potentiality of these remote area ,the results of this prospect iron were encourage where gold anomalies wane recorded at the Banded Iron Formation and concluded that :

- 1- The BIF ,occurs in highly folded and faulted beds ,similar to the Archeon BIF ,occurrences in other parts of the world .
- 2- The BIF deposits characterized by their huge volume up to 250 meters width and attains several kilometers in the strike length .
- 3- Mineralogical studies revealed that opaque minerals are goethite ,hematite and magnetite with sulphide traces .
- 4- Chemical analyses show that iron oxides content range from 25% to 65% ($Fe_2 O_3$)
- 5- Most of the analyzed samples either by (F.S.A) or spectral (S.P.A .) are gold bearing . Gold contents ranges from 0.3 to 5.7 g/ton .According to the hand data ,it is strongly recommended to conduct a more detailed exploration program in order to outline the more rich zones within the ore bodies .
- 6- Banded iron formation associated with quarzo-feldspathic gneisses need further study .
- 7- Gold mineralization in Al Uwaynat and Arkenu regions are confined to quartz veins , Altaration zones ,Banded Iron Formations ,Iron-bearing quartzite ,Ultamaffic rocks ,mafic and felsic dykes.
- 8- All this mineralized zones need further studies .

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